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Subject Analysis

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INTRODUCTION

This review updates the 1986 *ARIST* chapter on subject analysis by SCHWARTZ & EISENMANN. The aim is a global approach. Thus, efforts were made to locate and include studies beyond those performed or published in the United States. Although the items reviewed come mainly from the period 1986-1988, earlier works not covered by the previous *ARIST* chapter have occasionally been included. Some much earlier items are referred to when necessary for purposes of comparison or context.

Subject analysis here means the presence, identification, and expression of subject matter in document texts, databases, controlled and natural languages, information requests, and search strategies. From the user's viewpoint, subject analysis is tightly bound to subject access. Therefore, the means by which information on a subject can be retrieved from various sources is also pertinent.

The literature reviewed is grouped into six broad categories: 1) indexing theory and practice, 2) controlled vocabularies (including classification and subject headings), 3) search strategies and searching methods, 4) natural-language searching, 5) automatic indexing and related procedures, and 6) the use of citation relationships in information retrieval. Clearly these categories are not mutually exclusive, and some of the items reviewed could legitimately belong to more than one category.

INDEXING THEORY AND PRACTICE

General Discussions

Much has been written on various aspects of indexing over the years, but no really comprehensive book on the subject seems to have been produced, and those texts that do exist are now somewhat out of date. WEINBERG (1989) has compiled a volume of papers that, she claims, covers the "state of our knowledge and the state of our ignorance" on the subject of indexing. Because her book is based solely on papers presented at a 1988 conference of the American Society of Indexers, the individual chapters vary in quality. Topics covered include book indexing, automatic indexing, indexing software, database design, and the literature of indexing. Ironically, the outstanding chapter is about searching rather than indexing and is authored by SARACEVIC, who summarizes the results of the comprehensive study described elsewhere in this review (SARACEVIC ET AL.). He correctly points out that "people who do research on searching rarely, if ever, cite literature on indexing research and vice versa. Yet there is an obvious connection, and

perhaps more bridges need to be built between the research and practice of indexing and that of searching." This observation coincides closely with one of the conclusions made by LANCASTER (1968) 20 years ago as a result of the evaluation of MEDLARS (Medical Literature Analysis and Retrieval System) — namely, it is highly desirable that the indexers also be the searchers.

Elsewhere, WEINBERG (1988) hypothesizes that indexing fails the researcher because it deals only in a general way with what a document is "about" and does not focus on what the document offers that is "new" concerning a topic. She suggests that this distinction is reflected in the difference between "aboutness" and "aspect," between "topic" and "comment," or between "theme" and "rheme" (those elements expressing something "new" or unpredictable in a sentence), but she fails to convince that these distinctions are really useful in the context of indexing or that it might be possible for indexers to maintain them.

A related study is the doctoral dissertation by CROWE, who discusses the feasibility of indexing the "subjective viewpoint" of an author. She suggests that the indexer focus on the "problem situation" addressed by the author, including the questions addressed in the author's work.

Aboutness is a slippery concept. The subject content of a document is sometimes referred to as intrinsic aboutness. What the document may be used for, why it was acquired, and other variable external' considerations are referred" to as extrinsic aboutness. GORDON looks at indexing not in the context of aboutness as used by BEGHTOL (1986a) and KHANZHIN but in relation to the interdependencies of the document descriptions, queries, and matching algorithms of the information retrieval system in use. He argues that a change in any of the three parts of the system mandates alterations in the other two if the system is to operate effectively. COCHRANE (1985) also reflects this holistic point of view.

GRUNBERGER tested the assumptions that the frequency of a term on a page and the location of that term within a paragraph are good indicators that such a term would be selected in indexing. Neither of the hypotheses was supported.

AZUBUIKE & UMOH advocate maximum indexing, a concept that calls for exhaustively indexing a document using a variety of indexing strategies. While some would maintain that exhaustively indexing a document from both general and specific aspects leads to low precision in retrieval, the authors argue against this view.

CHANG refers to the limitations associated with permuted title indexing and citation indexing and concludes that intellectual effort in indexing is still necessary.

Based on the idea that knowledge is symbolic, VICKERY provides a review of methods whereby knowledge can be represented. The review includes discussion of the use of symbols and symbol structures, semantics, and roles, categories, and relations present in subject statements. The arrangement and representation of knowledge as reflected in classification schemes and thesauri are also touched on. In addition, work in the area of "semantic primitives" or "semantic factoring" is reviewed and leads to a brief discussion of several means of representing knowledge for reasoning, including symbolic equations, frames, and semantic nets. The review closes with a short description of a prototype reference and referral expert system developed by the author and his colleagues that uses many of the knowledge representation techniques reviewed.

The continual problem of the interaction of the subjective and objective in the organization and retrieval of information is addressed by NEILL through a review of the works of Brenda Dervin and Karl Popper as well as other writers whose works were influenced by or amplify Dervin and/or Popper. The effect of the subjective in classificati6h and in indexing is discussed along with its impact on information retrieval, leading to a description of an information system

called Projekt INSTRAT, which utilizes some of Popper's concepts. The review concludes that although subjective and objective viewpoints follow different paths, their final solutions are similar.

BLAIR (1986) looks at indeterminacy in indexing — i.e., the probability that a term the user chooses will be in the set of potential terms available to the indexer *and* in the set of terms used by the indexer. Increasing the number of terms assigned to a document increases the chances of a hit, but success is not guaranteed. Blair suggests that the user should always identify a highly relevant document as a model for further searching.

CROFT (1987) outlines some areas of research in artificial intelligence, such as the development of expert systems, that should be fruitful in solving the problems of indeterminacy in both indexing and term selection for retrieval. Expert systems are designed to assist the user in query formulation and selection of relevant documents.

Predominantly nonverbal fields of knowledge present special difficulties in indexing. Geographical and geological mapping are two primarily visual fields that are not served well by verbal systems. GRANDE explores the ideograph as a model for database design, indexing, and retrieval of geological information, while MARKEY (1984) discusses consistency aspects in the indexing of visual materials.

The requirements for indexing in videotex and related systems are addressed by YEATES, with special reference to the British Prestel system. Prestel's indexing approaches include: menu-controlled reference frames, alphabetical name and subject indexes, keyword indexes, gateway indexing to other systems, online and print indexes, user-controlled indexes, mnemonic page numbers, and Pagemarker — a "bookmark" feature that allows users to tag specific pages for later rapid recall.

ASRIBEKOV deals with the broad subject of textual compression in information systems. Conversion of primary (journal) text to alternative forms (e.g., reviews and monographs) and to secondary representations (indexes and abstracts) are both covered.

Precoordinate Indexes

It is a curious anomaly that in an age in which the online searching of databases is commonplace, greater interest exists than ever before in the characteristics of precoordinate indexes in printed form. Moreover, literature on this subject continues to pour out. The reason, of course, is that computer processing provides an efficient means for generating multiple entries systematically from a single input supplied by an indexer. A book by CRAVEN (1986b) gives a useful overview of the subject (i.e., precoordinate or "string" indexing), although its value is reduced by the fact that some of the approaches included are not described clearly or illustrated with sufficient examples. Elsewhere CRAVEN (1986a) describes a coding scheme for expressing relationships among terms within a string used as input to index-generation programs. He also examines the possibility of extending the concept of string indexing from index display to the provision of descriptor phrases for proximity searching (CRAVEN, 1988).

One of the most sophisticated approaches to precoordinate indexing was developed by Jason Farradane more than 30 years ago. Termed "relational indexing," the method involves the use of role indicators (or "operators") to express precise relationships among terms. Farradane's work is described by BROOKES.

SCHNELLING (1984; 1986) points out the limitations of alphabetical subject catalogs based on a controlled vocabulary of subject headings (German libraries have never favored this approach). He proposes a method combining standardized and free terms. For each broad area

covered by a catalog it is necessary to derive a "pattern" — a set of categories into which the literature seems to fall naturally (e.g., a pattern for materials science might include composition and structure, physical properties, mechanical properties, applications, fabrication, deterioration and failure, and so on— essentially a type of facet analysis). These categories can then be adapted as standardized subject headings or subheadings. However, within the general framework provided by this pattern, it will be necessary to index in more detail by the use of free (uncontrolled) terms. He illustrates the approach advocated by a discussion of indexing requirements in the field of literary scholarship in general and Shakespeare in particular. The somewhat grandiose title applied to this approach— "pattern indexing"—suggests something quite new. In fact, the only thing claimed is that while a broad terminological structure can be preestablished for any field (based on "literary warrant"), the fine details of indexing will always require the use of free terms. While this is eminently sensible, it is hardly original. This fact is recognized by HARRIS, who refers to the process of indexing with a combination of controlled and uncontrolled terms as use of a "part-controlled vocabulary." He suggests that this technique is "probably widely used in various kinds of information service, but has not been formally recognized as a design option for librarians" (p. 133).

The string indexing system that has generated the most literature, of course, is PRECIS (Preserved Context Indexing System), and it continues to do so. DYKSTRA (1985) contributes a primer on the subject. MAHAPATRA & BISWAS study the interrelationships of the role operators used in PRECIS indexing, and DYKSTRA (1987) suggests that PRECIS'S clear rules lend themselves to use in automatic indexing. Somewhat related to PRECIS is POPSI (Postulate-based Permuted Subject Indexing). BISWAS & SMITH describe a variation of POPSI that they refer to as a computerized deep structure indexing system.

One of the oldest and most respected of the printed indexes is that produced by Chemical Abstracts Service (CAS). The indexing policies of CAS are discussed by ROWLETT, and the history of subject indexing at CAS is covered by ZAYE ET AL.

On the international front, BIELICKA & SCIBOR review indexing trends in Poland and compare them with international trends. GHANI explores the potentialities and problems of using uniterm (i.e., single-word) indexing in the Arabic language. Many of the problems outlined center around problems of standardization in the language itself.

Quality of Indexing

It is difficult to look at the quality of indexing in isolation — i.e., without evaluating some information retrieval "system" in which the indexing is only one of several factors affecting overall performance. Indeed, more work may have been done on consistency of indexing than on quality. Recently, however, some interesting approaches to the evaluation of indexing have been introduced.

WHITE & GRIFFITH use methods external to the indexing system being studied to establish a set of documents judged to be "similar in content." Using sets of this kind (they call them criterial document clusters) as the basis for evaluation, they look at three characteristics of the index terms assigned to items in the set within a particular database:

- The extent to which terms link related items. The obvious measure of this is the number of terms that have been applied to all or most items in the set. The items can be considered closely linked if several subject terms apply to all of them.
- The extent to which terms discriminate among these sets within the database. The most obvious measure of this is the frequency with which terms that apply to most

documents in the set occur in the database as a whole. Very common terms are not good discriminators. For example, in MEDLINE the term "human" may apply to every item in a set but is of little value in separating this set from others since it applies to so many items in the database. On the other hand, terms that occur rarely in the database will be useful in highly specific searches but of little use in identifying somewhat larger sets.

- The extent to which terms discriminate finely among individual documents. Rarity is an applicable measure here also. So is the exhaustivity of the indexing: a term may apply to all items in a set, but cannot discriminate among its members; the more additional terms that are assigned to each member, the more individual differences can be identified.

To look at quality in this way, one must first establish the test sets, retrieve records from a database for the members of each set, and study the characteristics of the terms assigned. White and Griffith used the technique to compare the indexing of their test sets in different databases: MEDLINE was compared with PsycINFO, BIOSIS Previews, and Excerpta Medica. A comparison of databases in this way is a check on the assumption that test-set items are in fact similar in content. White and Griffith used co-citation as the basis for establishing their test sets, although other methods, including bibliographic coupling, could be used.

The value of this work is limited by the fact that only very small clusters (three to eight items) were used. Moreover, the validity of the method as a test of human indexing depends entirely on one's willingness to accept a co-citation cluster as being a legitimate standard. One could make a persuasive argument that it makes more sense to use expert indexers as a standard for judging the legitimacy of the co-citation cluster.

WHITE & GRIFFITH claim that the method is useful to a database producer as a check on the quality of indexing, and they present examples of terms that should perhaps have been used by MEDLINE indexers or added to the controlled vocabulary. However, such "quality" checks can be done more simply. Sets of items defined by a particular term or terms (e.g., "superconductors" or "superconductivity" occurring as index terms or text words) can be retrieved from several databases and their indexing compared without the use of co-citation as a standard. In fact, this type of study has also been done by the same group of investigators (MCCAIN ET AL.). For 11 requests posed by specialists in the medical behavioral sciences, comparative searches were performed in MEDLINE, Excerpta Medica, PsycINFO, SciSearch, and Social SciSearch. In the first three databases the searches were performed on: a) controlled terms, and b) natural language. In the citation databases, searches were performed: a) using the natural language of titles, and b) using citations to known relevant items as entry points. While the purpose of the investigation was to study the quality of MEDLINE indexing, little was discovered that could be posed as recommendations to the National Library of Medicine (NLM) on indexing practice, although some recommendations on indexing coverage could be made.

The most important findings of the study were that: 1) the incorporation of natural-language approaches into search strategies resulted in significant improvements in recall compared with the use of controlled terms only; 2) citation retrieval should be considered an important adjunct to term-based retrieval because additional relevant items can be found using the citation approach; and 3) no single database is likely to provide complete coverage of a complex multidisciplinary literature.

The work reported by White and Griffith and by McCain et al. forms part of a series of investigations done at the College of Information Studies, Drexel University, to evaluate various

aspects of NLM's coverage and handling of the literature of the medical behavioral sciences. GRIFFITH ET AL. present an overview of all the studies, including the coverage of the databases, the quality of the indexing, and the results of searches in the medical behavioral sciences.

AJIFERUKE & CHU are critical of the "discriminating index" for terms used by White and Griffith, which takes into account how many times a term is used within a database but not the size of the database. They propose a new measure that does. HRAŠOVA & JANÁKOVÁ conclude that consistency in keyword indexing is greatest when very few or very many keywords are chosen. This makes sense. It is relatively easy to agree on the two or three most important terms. Consistency will begin to decline after this but is likely to increase again when virtually all terms that could possibly be assigned to a document have been assigned (a kind of "saturation effect").

One factor that might have some influence on the quality of indexing is the availability to the indexer of appropriate reference tools. BAKEWELL gives details on almost 200 books of possible value to indexers.

To improve indexing and classification procedures, to make them more responsive to user needs, it is necessary to understand the bases on which people categorize or group documents in everyday life. KWASNIK, for example, is looking at the categories into which people sort their mail. She presents some preliminary results based on her observations of eight members of a university faculty.

The average number of terms assigned to a document in indexing (frequently but misleadingly referred to as "depth") tends to have a significant effect on the performance of a retrieval system. CLEVELAND & CLEVELAND studied the effect of indexing depth on retrieval performance for conventional Boolean searching methods and for the "indirect method" of retrieval devised by GOFFMAN. They concluded that the latter, unlike the former, is relatively insensitive to indexing depth. The indirect method involves the matching of a query against document clusters, which are established on the basis of term co-occurrence, the identification of the cluster that best matches the query, and the identification of the cluster member closest to the query. This document can then be used to locate other related items. CLEVELAND ET AL. also tested the hypothesis that when the indirect method is used for searching, indexing from full text (as opposed to titles, abstracts, or references) is not essential to optimum retrieval. They conclude that optimum retrieval results can be achieved with less than full text when the indirect method is used.

CONTROLLED VOCABULARIES

General Discussions

The term "index language devices," which can be traced back more than 20 years, is somewhat misleading in that some of the "devices" referred to (e.g., role indicators) are legitimate components of index languages while others, such as term weighting, are outside the index language per se and are more correctly referred to as "indexing devices." A detailed analysis of two important devices — weighting and relational indicators — is provided by KÖRNER. Role and relational indicators, various approaches to the linking of terms, facets, human and automatic weighting are all included in his review. KRISTALŃYI ET AL. suggest the use of the universal facets of time and space as a way to increase compatibility in various automated systems in the Soviet Union.

CHANDRASEKHARAN ET AL. apply graph-theoretic techniques to solve the

"minimum vocabulary problem" for a dictionary — i.e., to identify the smallest set of words needed to define all the words in the dictionary. They claim that the minimum vocabulary principle can be applied to reduce the size of a controlled index language but fail to elaborate on this application.

EASTMAN reports on a preliminary study of the extent to which overlap in postings occurs among hierarchically related terms in a controlled vocabulary, using data from MEDLINE and Medical Subject Headings (MeSH), and she considers the implications of the overlap phenomenon for searches involving negations.

NELSON & TAGUE discuss the distribution of index terms over a collection of documents. They point out that a rank-frequency distribution well describes the distribution of terms of high frequency, while a frequency-size distribution provides a better picture of the distribution pattern for low frequency terms. They describe a "split model," using a rank function for the high frequency terms and a size function for the low frequency terms, the point of transition between the two being determined empirically or by rule. On a more practical level, NELSON found that users of an online public access catalog (OPAC) at the University of Western Ontario tend to employ terms that occur very frequently in the catalog.

The construction of controlled vocabularies involves the establishment of relationships among "subjects." JOHANSEN (1987a; 1987b) makes a distinction between relationships established on "linguistic" and "nonlinguistic" levels and attempts to present a "method of disclosing the structure of a subject by examining its constituent elements and their mutual relationships." SUOMINEN deals with the subject of syntactic relations in index languages.

STIEG & ATKINSON compare indexing and indexing languages in the ERIC, LISA, and Library Literature databases as one aspect of a broader comparison of these three sources.

Bibliographic classification schemes, lists of subject headings, and thesauri are all examples of index languages — i.e., vocabularies that can be used to represent the subject matter of documents and of information needs. BIELICKA ET AL. and JABRZEMSKA & SCIBOR review the types of index languages in use in Poland, and STANCIKOVA presents a similar review for Czechoslovakia.

Information retrieval in the humanities is generally considered to be more difficult than it is in the sciences because the terminology used by humanists is less precise. WIBERLEY explores this situation by studying the entry terms used in leading encyclopedias and dictionaries in the humanities. He concludes that although some of the terms are imprecise, most of them are quite precise and consist of names of individuals or of creative works; this finding suggests that subject access in the humanities may be less of a problem than previously supposed.

SANTAVICCA points out the crucial role that a knowledge of languages plays in the selection of terms for indexing, thesaurus control, cross-references, and access points. He suggests that the manipulation of text in international databases requires a kind of trilingualism: a knowledge of the user's native language, a knowledge of the foreign language in question, and a knowledge of the system's operating language. An inability to exploit any of these will result in diminished system performance. He concludes that the importance of studying foreign languages must be recognized if users are to be well served.

Classification Schemes

In a brief overview, ROMAN provides an introduction to classification, which is seen as the adaptation of prevalent philosophical views (from Plato and Aristotle on) to library materials. She examines recent changes in thinking (such as the work of Piaget, Kuhn and Popper) that have

influenced current views of classification. BEGHTOL (1986b) discusses classification in terms of the underlying justification (warrant) of the system. In the past, classification systems have been based on literary, scientific, philosophical, or educational warrant. She suggests that more investigations will occur in the future in the area of "inquiry warrant" systems built as direct responses to user demands. While she seems to trace the idea back only to 1984, it was discussed as "user warrant" by LANCASTER in 1972.

In a comparison of five classification schemes for physics and chemistry, SNOER considers the impact of online catalogs on classification systems. The schemes examined are the Library of Congress Classification system (LCC), the Dewey Decimal Classification system (DDC), the Universal Decimal Classification system (UDC), and the former and present systems of the University of Copenhagen. The author stresses the value of using UDC's Common Auxiliary for Place (i.e., geographic subdivision) in existing call numbers to enhance retrieval. She concludes that radical revision of classification to suit the online environment is not necessary but that improvements can be made to existing schemes.

In a more global view than is often encountered, HOLLEY examines the impact of electronic technology on classification and subject cataloging and speculates on how this might affect third world countries. He fears that changes occurring in approaches to subject access and subject analysis in the developed countries will not take the needs of the third world into consideration. The International Federation of Library Associations (IFLA) is encouraged to provide a forum for the third world to cope with this situation.

The value to users of an index to a classification scheme is observed by NAKAMURA, who points out that even though such indexes are often rejected on the grounds of inflexibility, the very nature of such a fixed system is helpful for the user who is unfamiliar with a particular scheme. However helpful an index may be, it cannot fully compensate for the difficulty in using classification as a search tool. The author suggests a number of approaches to concept classification as possible remedies.

Since its controversial entrance into American public libraries over a century ago, fiction has remained something of a stepchild in terms of access. BAKER, BAKER & SHEPHERD, and SHEPHERD & BAKER examine the application of classification to fiction in American public libraries. Their survey of the literature indicates that patrons find classification a useful tool in locating the types of books they want. Suggestions for further study are included. On the same topic, SAPP describes four classification schemes for fiction: LCC system, DDC system, Frank Haigh's fiction classification scheme of 1933 (HAIGH), and L. A. Burgess's scheme of 1936 (BURGESS). These are evaluated along with discussions of shelving schemes, subject headings, and topical access to fiction through standard print indexes. Mention is also made of experiments by the Danish librarian Annelise Mark Pejtersen in online subject indexing for fiction (PEJTERSEN & AUSTIN). SAPP recognizes the difficulties in classifying fiction and recommends further study to determine if the need for classification here justifies the effort.

New systems, and modifications to older ones, are evolving in response to demands for more effective subject retrieval. LIU-LENGYEL describes the development of the Chinese Classification System over 2,000 years and notes the problems that lack of standardization has caused in Chinese libraries. This may have been somewhat remedied by the adoption of the new Chinese Book Classification system as a standard in 1981. SUKIASYAN examines trends in classification in the Soviet Union.

Several projects have explored the value of classification schemes for retrieval in OPACs. Some researchers are looking at the LCC system and the DDC system for this purpose. Using

OCLC MARC (machine-readable cataloging) records as a research base, MARKEY (1987) and MARKEY & DEMEYER (1986a; 1986b) have tested the potential of the DDC system for retrieval. They demonstrate that, used in combination with Library of Congress Subject Headings (LCSH) and keywords in title, DDC can increase recall and retrieve relevant items not retrievable by any of the other fields on the record. CHAN (1986a) has examined theoretical issues related to whether or not the LCC can be used to enhance subject retrieval in an online catalog, while WILLIAMSON (1986a; 1986b) is also working on a project to test the potential of using LCC for subject retrieval. HUESTIS reviews strategies for overcoming the major problems involved in the use of LCC in OPACs.

KHOSH-KHUI has looked at the relationship between length of class numbers in LCC and DDC and subject specificity. Although the length of number in both schemes does increase with specificity, it is not in itself a good indicator of specificity of subject headings assigned to items or of the number of headings assigned.

GOPINATH discusses the use of classification schemes and thesauri in a symbiotic relationship that can improve information retrieval. The concept of a "thesaurofacet" or "classaurus" — a device that incorporates features of a faceted hierarchical scheme with those of a thesaurus — is a practical application of this symbiotic relationship (DEVADASON). AITCHISON looks at two thesauri that have used the H. E. Bliss classification as a source for construction and considers the merits of using the second edition of Bliss for this purpose.

O'NEILL ET AL. look at the problems involved in mapping from one classification scheme to another, with particular reference to the LCC and the DDC systems. They introduce the notion of "class dispersion" as a measure of the ease with which a class in one scheme can be mapped to another scheme. DUNAYEV & POLYAKOV describe the problems involved in deriving a mathematical description of classification schemes.

Subject Headings

The emergence of OPACs has also caused a revival of interest in subject headings, as they are traditionally used in libraries, and the limitations of these vocabularies for effective subject access in the online environment. WYKOFF provides a brief overview of the history of the use of subject headings in online access. MASSICOTTE describes how displays of subject headings in OPACs can be made more browsable, while MARKEY (1988) discusses the integration of Library of Congress Subject Headings (LCSH) in machine-readable form into online catalogs.

Over the years LCSH has been the subject of much criticism. COCHRANE (1986) groups the criticisms into four categories of needs: 1) the need to improve the form of headings and to add more scope notes, 2) the need to improve the cross-reference structure, 3) the need to improve subdivision access, and 4) the need to improve the syndetic (i.e., cross-reference) structure of the system by use of classification. She examines suggestions for improvements and discusses how these fit into the online environment.

In an article that begins by reiterating the criticisms of Anglo/Western bias in LCSH and the inability of the Library of Congress (LC) to keep the vocabulary up to date, HENIGE presents a further concern that headings are not being changed to reflect current scholarly consensus. To be effective in reference work, he says that headings must be accurate and in step with current scholarly thought. LC, however, has always taken the position that LCSH should reflect the content of published literature (literary warrant) rather than the cutting edge of scholarly research.

DYKSTRA (1988a; 1988b) points out that the 11th edition of LCSH (LIBRARY OF CONGRESS. SUBJECT CATALOGING DIVISION, 1988) adopts the very precisely defined

terminology of thesaurus construction, but she argues that its use of "broader term," "narrower term," and "related term" is misleading because LCSH does not maintain the precise logical relationships implied by these terms in a carefully constructed thesaurus. LCSH can only be considered as a list of accepted subject terms used in LC; it is not a true thesaurus.

It has always been difficult to determine the policies and practices that LC adopts vis-à-vis LCSH. With the exception of Haykin's guide published in 1951, there has been very little explanation available (HAYKIN). The revised edition of LC's *Subject Headings Manual* (LIBRARY OF CONGRESS. SUBJECT CATALOGING DIVISION, 1985) and the second edition of *Library of Congress Subject Headings: Principles and Application* (CHAN, 1986b) provide two excellent sources to guide the librarian in using the subject headings for items in a collection. Knowing how headings are interpreted and used by LC will help promote consistency among libraries in their application. FROST & DEDE have studied the compatibility between LCSH and the use of subject headings by one large research library.

Methods by which a controlled vocabulary is updated are another matter of general interest. A study by BACKUS ET AL. tested two hypotheses concerning the annual revision of the National Library of Medicine's (NLM) MeSH vocabulary. It was hypothesized that new terms are added to the vocabulary when their broader terms have increased in number of postings and that the distribution of terms in the hierarchical "trees" of the vocabulary would reflect the distribution of terms in search requests made to the system. Neither hypothesis was supported.

MCCARTHY discusses the extent to which consistency occurs in the assignment of headings in order to bring like works together. She concludes that consistency is not as high as it should be and proposes an increase in the number both of headings assigned to an item, as well as cross-references, as possible remedies. She also recommends that catalogers examine the literature on the subject in question to see what headings have been applied in the past. She believes that the use of online catalogs increases the importance of consistency in assigning subject headings and also simplifies its achievement.

MILLER presents a very brief outline of the application of automation to the production of LCSH and points out the advantages and disadvantages of the program.

Many libraries have made it a standard policy to review and revise the subject headings assigned to catalog records by member libraries of OCLC, Inc. SALAS-TULL & HALVERSON evaluate this practice in light of the time and expense involved in comparison with the number of changes libraries actually make to the OCLC records. They examined revisions made by research, academic, and public libraries and found that there was little difference in the number of revisions among the three types of libraries and that the total number of revisions was lower than expected. They conclude with several suggestions for cataloging departments that use subject heading review policies.

Since the 1940s there has been interest in a uniform code for subject headings. With the general adoption of the *Anglo-American Cataloguing Rules,* 2nd edition *(AACR2),* interest in a similarly uniform guide for subject access has been renewed. STUDWELL & ROLLAND-THOMAS suggest a form for such a code and urge an international effort to develop a standard code. In the same spirit, STREBI offers examples of revision and retrospective conversion of subject headings performed by the Austrian National Library as models for other libraries to consider.

The use and effectiveness of subject headings for biomedical materials have also been the subject of recent research. MASARIE & MILLER compare terms used by health professionals with the standardized vocabulary found in MeSH. Fifty hospital charts were randomly selected

and subjected to a computer analysis that matched terms with two MeSH-based vocabularies; the first consisted of MeSH terms, and the second consisted of MeSH terms plus cross-references (entry terms). Approximately 50% of the words used in the charts matched the MeSH-related vocabularies, with about 40% of these proving to be exact MeSH terms or entry terms. Also working with MeSH, RADA ET AL. evaluated entry terms and tested a method for producing new entry terms. Documents indexed by MeSH terms were compared with documents indexed automatically to see if the automatic indexer could map from title words to controlled terms through the use of entry terms better than it could without using entry terms. Some entry terms were found to be ambiguous. In a method for producing new entry terms, the authors present an algorithm to map terms from the *Systematized Nomenclature of Medicine (SNOMED)* to MeSH. While the new *SNOMED* terms were not helpful in indexing, they did suggest how MeSH might be improved. A new algorithm was formulated to join the two sets of terms, and the combined *SNOMED* /MeSH vocabulary was judged to permit improved indexing over the MeSH terms alone.

Thesauri

WEINBERG & CUNNINGHAM provide a brief comparison of online thesauri with print versions. The interfaces for a number of different vendor systems are evaluated, and the article includes recommendations for improving online thesauri. CHAN & POLLARD provide an annotated directory of thesauri used in online databases.

The linking and evaluation of thesauri are necessary tasks in improving retrieval systems. RADA presents a number of considerations in connecting and evaluating thesauri. Experimental linkings of MeSH with the *SNOMED,* CMIT (Current Medical Information and Terminology), and PDQ (the National Cancer Institute's retrieval system) thesauri are discussed. In these experiments, similarities are identified and differences are exploited to generate better thesauri. MILI & RADA also report on efforts to merge thesauri to create more powerful vocabularies, and MANDEL (1987) reviews the problems involved in integrating thesauri and other forms of controlled vocabulary within an online bibliographic network.

SCHONDORF presents a study utilizing the Thesaurus Database developed by the Gesellschaft fur Information und Dokumentation in Frankfurt, which examines unconventional relationships among thesaurus terms. The study presents examples of how these relationships provide orientation support within the thesaurus's vocabulary for indexing and retrieval. ROSTEK & FISCHER describe the computer "modeling" of a thesaurus within a frame system with a graphical interface. BELLAMY & BICKHAM deal with the development of a thesaurus for the subject cataloging of books in a special library in biomedicine.

SEARCH STRATEGIES AND SEARCHING METHODS

General Discussions

An enormous study of factors affecting the performance of online searches was undertaken over a period of several years at the now defunct Matthew A. Baxter School of Library and Information Science at Case Western Reserve University. The methodology and results for the final phase of this project are presented by SARACEVIC ET AL. The study involved 40 users, each providing one question, and 39 searchers (three members of the project team and 36 individuals from outside). Interviews with the users were tape recorded. For each question, nine searches were performed, four by project staff and five by outside searchers, for a total of 360

different searches. A related experiment was also undertaken, involving the classification of user questions by 21 judges. The results of the searches were evaluated by the users in terms of relevance and utility. The bewildering variety of data collected during the project makes effective summarization virtually impossible. Perhaps the most significant finding was that different searchers were likely to have quite different interpretations of a question and, thus, used different search approaches and retrieved different items. Moreover, each searcher tended to find some relevant items not found by the others, although the chance that an item would be judged relevant increased with the number of searchers retrieving it. The investigators suggest that these results argue the need for multiple searches for the same question by different searchers, but an alternative conclusion might be that a team approach to the analysis of a question and a consensus approach to an initial search strategy might be the preferred mode of operation.

Earlier FIDEL (1985) had also discovered that experienced searchers show little agreement in the selection of terms, and even earlier studies (e.g., BATES, 1977; LILLEY) consistently revealed that users of card catalogs also tend not to agree much on what terms to use in searching for items on a particular topic.

HARTER looks at problem-solving attitudes and abilities of searchers as factors affecting search success. FAIRHALL categorizes the various skills associated with searching performance, while SCHIFFMANN reminds us of the value of "hedges" (i.e., terms or term combinations that cut across the hierarchical structure of a controlled vocabulary) in the handling of repeated search requests. VIGIL (1988) contributes a major monograph on the searching of online databases, including psychological factors in searching.

Over the past 25 years a number of attempts have been made to measure unobtrusively the quality of reference services offered by libraries. Such studies have focused on the ability of libraries to answer factual questions. MCCUE has now pioneered the unobtrusive evaluation of online searching in libraries. Twenty-one public libraries throughout the United States were each asked to perform the same search in two different databases; the searchers did not know that they were being tested. Two "outside expert database searchers" evaluated the results. Using a point system, each search was scored on strategy, general techniques, and results. General techniques covered such aspects as searcher mistakes in entering terms or use of incorrect procedures. Results were also given numerical scores; a worthless citation earned no points, an excellent one earned 8. The library scores ranged from 419 to 155. McCue concludes from her statistical analysis that the only variable that correlated positively with high search scores was the number of items retrieved. This is hardly surprising. In effect the scoring method takes recall into account since it gives positive scores to "useful" items but not precision (since it gives zeros rather than minus values to "worthless" items). The entire method of scoring, however, is of dubious quality. In the long run it is the results that matter, so it seems pointless to devise a scoring method that takes not only results but search strategy and search technique as well into account.

HANSEN compares the results of a group of inexperienced subjects who performed manual searches followed by online searches with the results achieved by a matched group of subjects who performed online searches followed by manual ones. The differences in the results were not statistically significant. Nevertheless, she concludes that inexperienced searchers may get the best results when performing a manual search after an online search, at least in the case of "a large and complex topic with an expanding literature," a conclusion that receives very weak support from her data.

In a doctoral dissertation, DALRYMPLE compares the searching of card catalogs with the searching of online catalogs, looking at the activity as essentially a problem-solving task. Within

her experimental setting, users found more relevant items and were more satisfied with their results from the card catalog. Users spent more time and reformulated their strategies more often when using the online catalog.

The search patterns of users of the CATLINE database of NLM are analyzed by TOLLE & HAH and compared with the search patterns of MEDLINE users.

FIDEL (1986) discusses how analysis of the search behavior of human intermediaries can be used to identify rules by which such experts select "search keys" — descriptors from a controlled vocabulary or free-text terms. She claims that when more research has been performed on expert search behavior, it should be possible to build a knowledge base for use in an intermediary expert system for online searching. By observing 47 searchers in action, FIDEL (1988) concludes that free-text terms and descriptors are selected with about the same frequency. However, those who prefer the free-text approach and avoid controlled vocabularies are more likely to be searchers on science topics who search several databases for each request.

The evaluation of the results of a search involves some criterion for judging the relevance of retrieved items. EISENBERG & SCHAMBER review various approaches to the definition of "relevance" used by earlier writers and propose a "user-centric-cognitive model" that views the user as the "central and active determinant of the dimensions of relevance." In a related paper, HALPERN & NILAN discuss the subject of relevance in terms of "source evaluation," the weight that a person places on a source of information beyond its substantive content — authority or expertise represented, uniqueness, and so on. After using judges to rate documents on both relevance and utility, REGAZZI claims that no operational difference exists between relevance-theoretic and utility-theoretic models of evaluation.

WAGNER examines the cause of "false drops" in online searching. They are less prevalent in searches that use only controlled vocabulary terms, but in any case they account for only a small percentage of errors, and that retrieval error is, to some degree, unavoidable, especially in searches seeking high recall. The author stresses awareness of the causes of false drops and advises that the professional be able to explain their occurrence to the user.

BLACKSHAW & FISCHHOFF view online searching as a decision-making process. Volunteer searchers were observed while performing author, title, or subject searches in an online catalog in a public library. The authors report that searcher performance resembles that revealed in studies of decision making in other contexts. BELLARDO looked at variables that might affect the performance of online searchers, using two test searches with students from six different library schools. Findings suggest that differences in performance can be attributed to general verbal and quantitative aptitude, artistic creativity, and an inclination toward critical and analytical creative thinking, but the associations are all very weak. High intelligence and other factors often cited as important attributes may not be *necessary* for high performance. Bellardo claims that searching performance may not be predictable on the basis of cognitive and personality traits.

End-user searching has become increasingly common with the growth of home computers, favorable searching rates for the home user and, most particularly, the emergence of more and more databases on CD-ROM. OJALA looks at who end users are, where they are, and why they are searching and makes some projections for the future. SEWELL & TEITELBAUM report the results of investigations of end-user searching of NLM databases over 11 years through transaction logs, interviews, and questionnaires. SULLIVAN ET AL. compared end-user searching with delegated searching and discovered that the end users were no less satisfied with their results, retrieved fewer items, and achieved a high precision. All aspects of end-user searching are reviewed in a compilation by KESSELMAN & WATSTEIN.

End-user searching, in some environments at least, may require a user-friendly interface to make the search process as simple as possible. POLLITT describes one approach, based on use of a menu, that has been developed at NLM. Called Men USE (Menu-based User Search Engine), it is an improved version of an earlier prototype, CANSEARCH. Pollitt claims that it "provides inexpensive, high-quality, subject-specific browsing and searching of the MEDLINE database for users who have no training or experience in information retrieval" (p. 11).

The interface described by BATES (1986) is intended to help users develop their own search strategies rather than to be an automatic "transparent" aid to the user. WILLIAMS discusses the wider issues involved in the design of transparent systems and describes a number of approaches, which she categorizes as gateways, front ends, intermediaries, and interfaces. However, her article is tangential to this chapter because it deals more with interface technology than with interface content. INGWERSEN emphasizes the importance of browsing facilities in solving search problems.

Information retrieval studies have increasingly taken the viewpoint that computer-human interfaces can be better designed if they are based on the concept of an adaptive, cognitive model. A review of cognitive models in information retrieval by DANIELS examines recent literature in this area, mainly from the standpoint of the user. A number of natural-language and controlled-vocabulary information retrieval systems that use cognitive models are discussed. The review concludes that cognitive models in the various systems work reasonably well because they function in constrained environments. Suggestions for further incorporation of cognitive models in future systems designs are offered.

VECCIA describes nine online systems that can be used to search the *Washington Post.* She compares the various types of searches the systems permit and notes items excluded from indexing.

The downloading of bibliographic records from online searches has become increasingly common. LARGE discusses the subject, including downloading from CD-ROM databases, and looks at the reuse of downloaded records in local databases. JAMESON treats downloading and uploading in greater detail, including legal aspects.

Searching in Online Library Catalogs

Traditionally library catalogs have provided somewhat limited capabilities for searching by subject. The replacement of the card catalog by online public access catalogs (OPACs) has brought about a great resurgence of interest throughout the library profession in all aspects of subject access. For one thing, it has been found that the proportion of catalog searches that are subject searches has tended to increase considerably as OPACs fall into place. LIPETZ & PAULSON confirm this trend in a "before and after" study at the New York State Library. FROST (1985; 1987) studied catalog users at the University of Houston and concluded that students search more often by subject than do faculty. However, on the basis of a study at the City University (London) prior to the automating of their catalog, HANCOCK suggests that subject searching of manual catalogs may have been more prevalent than previously thought. KASKE has found great variability in the proportion of OPAC searches that are subject searches — by hour of day, day of week, and week of semester.

In discussions of online catalog development in libraries two approaches are particularly evident. One is to improve the interface between user and system, and the other is to enhance or augment the system itself. An analysis of online subject searches led one group of librarians and information specialists to conclude that an online catalog must compensate for a user's inability to

match his or her subject headings exactly with those of LCSH, must provide more than one searching option (such as keyword, controlled-vocabulary, and call-number searches), and should permit users to refine large retrieval sets (MANDEL, 1986). HILDRETH also argues for a more interactive interface between the user and the system. One essential feature is to provide the user with information concerning the status of the search as it progresses.

The Subject Access Project performed at Syracuse University in the late 1970s (ATHERTON) determined that augmenting subject headings of traditional bibliographic records with terms from tables of contents and back-of-the-book indexes may be an efficient and relatively inexpensive way to improve subject access in the catalog. BYRNE & MICCO describe a study in which an average of 21 multiword terms, drawn from indexes or tables of contents, were added to MARC records for 6,000 books. Results of their studies indicate that searches of these augmented records achieved much improved recall compared with searches on titles or subject headings. DIODATO considers the same issue from a slightly different point of view when he studies readers' descriptions of books to determine if the descriptions match terms from the tables of contents and indexes. He concludes that tables of contents and indexes are two sources of terms that are likely to reflect terms that the user would use in searching for the books.

JAMIESON ET AL. have compared the searching of uncontrolled keywords occurring in bibliographic records with the searching of controlled terms in the records.
In recognition of the millions of bibliographic records presently in MARC format in libraries and information centers, CHITTY argues that the issue is not how to improve the information on the record but how best to use the information already present.

In actuality, the approaches to improving online catalogs are not a choice between whether the content is enhanced or the interface is improved. The content, the system/user interface, and the user are all integral parts of the system. DWYER points out that many developments in the bibliographic organization of libraries over the years have resulted in split files; he proposes that a total retrospective conversion be implemented as one means toward building better catalogs. Quality cataloging is a necessity because the accuracy of a system's content ultimately determines the success of retrieval. Because any transition to an online catalog involves choices and trade-offs, Dwyer stresses the importance of understanding the true costs involved and of understanding the users' requirements in order to make intelligent choices in questions of design.

LAWRY raises the question, "Can online catalogs be too easy"? The question indicates a concern that a system that appears to "think" for the user, by assisting the user in query formulation, search strategy selection, and evaluation of retrieved titles, is unintentionally misleading the user. Lawry stresses the importance of user education to make effective use of all the tools available in the library.

BATES (1986) presents a model of subject access in online catalogs based on three design principles: 1) uncertainty (subject indexing is indeterminate and probabilistic beyond a certain point); 2) variety (the variety in subject indexing is equalled by the variety of possible information needs that can be converted into catalog searches); and 3) complexity (the search process is more complex than most models assume). Bates argues that because indexing is characterized by variety (clearly demonstrated in the results of consistency studies), searching should no longer be based on the exact matching of terms but, instead, should help the searcher by displaying and "making it easier to explore" a variety of terms. Two tools proposed for improving search performance are an end-user thesaurus and a "front-end system mind"; the former is basically a vast entry vocabulary, and the latter is a semantic network, incorporating the entry terms, that allows a searcher to select from a variety of methods for generating semantic associations. The design approach proposed is

intended to be implemented in existing catalogs based on LCSH without the need for any reindexing.

Bates seems optimistic about the future of subject access in online catalogs. Not so BORGMAN, her colleague at UCLA. Based on studies of user behavior in subject searching — whether in library catalogs or in broader bibliographic databases — she concludes that "we do not yet have sufficient knowledge of user behavior to make improvements in system design" (p. 397).

Using the OKAPI (Online Keyword Access to Public Information) system, WALKER and WALKER & JONES investigated possible methods for improving subject searches. Automatic word stemming, synonym and cross-reference tables, and techniques for the approximate matching of words were all studied. They concluded that weak stemming is beneficial but that strong stemming is of doubtful utility (the former merely conflates singular and plural and removes the "ing" ending, while the latter removes all suffixes), that semiautomatic spelling correction should be used in online catalogs, and that cross-reference lists to allow automatic cross-referencing should be compiled using input from cooperating libraries. The cross-reference lists investigated were extremely simple, incorporating abbreviations (e.g., TV and television), noun-adjective pairs (e.g., Wales, Welsh), alternative terminology (e.g., Russia, Russian, USSR, Soviet Union), alternative spellings (e.g., csar, czar, tsar, tzar), irregular plurals (e.g., wife, wives), related terms (e.g., third world, underdeveloped countries, developing countries), numbers (e.g., 6, six, sixth, vi), and phrases. The phrases category is a little different from the others in that it consists of word combinations that should not be split up by searching algorithms because the meaning of the individual words is quite different from that of their combination (e.g., soap opera, pirate radio).

A much more comprehensive study was the doctoral research project of LESTER. Her objective was to determine what features would be needed in online catalogs to increase the success of users in matching their search terms with LCSH. Random samples of user subject terms, selected from the transaction logs associated with the NOTIS/LUIS (Northwestern Online Total Integrated System/Library User Information System) online catalog at Northwestern University were compared with LCSH. For user terms that failed to match the headings, 22 different strategies for achieving a match were investigated. Strategies that did *not* improve matching significantly were: use of a spelling checker, singular/plural conflation, phonetic spelling, exact matching in either subject or personal name authority files, and any process involving geographic name authority files. The strategies of right truncation, string searching with adjacency, and searching of keywords with Boolean operators significantly improved the matching whether or not the database were augmented by the inclusion of subject and name authority files and/or the ability to search all fields of a bibliographic record. It is interesting to compare Lester's finding on authority files — that they would have little effect on subject retrieval — with the finding of VAN PULIS & LUDY — that subject authority files are little used even when made available online.

MICCO ET AL. report on a project at Chatham College to develop an expert system capable of searching for and providing access to knowledge at the same level as a skilled reference librarian. The project proposes a system that will develop a user profile and diagnose information need, then connect the user to the information through a network interface that will include the use of CD-ROM technologies. The system is envisioned as using a Macintosh-style interface with windows and a mouse. It would have a three-tiered structure: the first level providing access tools (such as classification numbers, indexes, thesauri, and glossaries), the second providing access to monographs, and the third providing access to periodicals. As currently projected, the system will use the same types of heuristics employed by expert human searchers rather than the textual

keyword searching approach frequently used in computer-based systems. Several projects (e.g., by MARKEY & DEMEYER (1986a), CHAN (1986a), and WILLIAMSON (1986a; 1986b)) that have dealt with the use of classification schemes in OPACs were reviewed in the earlier section on classification schemes.

Information Requests

The effectiveness of a delegated search, of course, very much depends on how well a request made by a user actually reflects the user's information need. Much work has been done on user-intermediary interaction in information retrieval. AUSTER & LAWTON look at various characteristics of the pre-search interview as factors affecting the success of a search. ALLEN claims that the way users understand and express their needs will be affected by the cognitive structures (schemata) by which they have organized their knowledge of the topic and by the schemata introduced in the questions that intermediaries ask. Differences in personal schemata may mean that the same problem could result in completely different questions as filtered through the minds of different individuals. One major problem in user-intermediary interaction is that the personal schemata (frame of reference) of the user and that of the information specialist may be quite far apart. Moreover, various "external schemata" (such as the index language) may also exert strong influence on the interactions between user and intermediary. Somewhat related to Allen's work is that of DERR, who identifies five types of expressions used by individuals in making demands on information services; he discusses the implications of the differences for practices in information retrieval.

PETRUS points out that the imperfect nature of requests makes information retrieval an operation based on probability. The retrieval situation can be described by the theory of statistical solutions.

NATURAL-LANGUAGE SEARCHING

The searching of text by computer can be traced back to the late 1950s, but interest has continued to increase as more and more text (of abstracts or complete items) becomes accessible online. Based on studies performed with the full text of popular magazines, TENOPIR presents a useful but brief discussion of the relative effectiveness of various types of strategies for full-text searching. COVE & WALSH look at the feasibility of a browsing approach to searching text online. They describe a system that will display text extracts to prompt the user to select words. These can then lead to "associated words" — i.e., words occurring as the "nearest neighbors" of the words originally selected — which can generate further displays of text, from which additional "browse words" can be selected, and so on.

The type of text that is generally accessible online consists of relatively brief items such as journal articles, abstracts, or patents. Because of rapidly declining costs (due in part to use of CD-ROM), it is now becoming increasingly feasible to store and exploit the text of much longer items, but how useful would it be to be able to search the complete text of, say, monographs? Based on studies of how library patrons use nonfiction books, PRABHA & RICE conclude that systems that permit the searching of the full text of non-fiction books would be of value to the users of at least the academic libraries.

Over the years a number of studies have compared the results of searches in humanly indexed bibliographic databases with results of searches in full-text databases. The common finding is that full-text databases give greater recall but reduced precision. SIEVERT ET AL. confirm this by comparing results achieved in searching MEDLINE with those achieved through

searching two full-text databases in medicine; RO comes to the same conclusion in a different environment. Unfortunately, this type of result is frequently misinterpreted. The fact that a full-text database gives better recall than a database of humanly indexed bibliographic records has nothing to do with the properties of text per se; it is simply due to the fact that text records tend to be longer and thus provide more access points. A database of records indexed with an average of, say, 50 descriptors may well give better recall than a database of brief (say 100 word) abstracts, but one could change these results dramatically by greatly increasing the length of the abstracts or drastically reducing the number of descriptors assigned. It is the length of the record that is the major determinant of what is and is not retrieved, but this fact is sometimes overlooked.

AUSTIN examines some of the implications of natural-language searching, illustrating cases in which natural-language searches have failed. These failures are analyzed for possible solutions, leading the author to conclude that computers exacerbate rather than alleviate the need for vocabulary control. HOOD reaches a similar conclusion. Full-text searching tends to uncover details, whereas controlled-vocabulary searching tends to uncover broad concepts. He concludes that a comprehensive search would require more than one method.

Investigators at Syracuse University (BONZI & LIDDY; KATZER ET AL.; LIDDY ET AL.) have undertaken several related studies on what is assumed to be one of the problems of text searching — the implicit reference to topics through anaphora. For example, AIDS can be variously represented by "the disease," "it," and so on, in a text. In one study the anaphors occurring in abstracts were replaced by their referents. It was then determined what effect this replacement would have on term weighting, based on word frequency counts, and subsequently on retrieval. The results were inconclusive: in some searches the replacement improved the ranking of documents in search outputs, while in others it actually caused a deterioration of the ranking. It was hypothesized that this anomaly might be caused by the fact that anaphors sometimes refer to topics that are integral to a text, while at other times they refer to topics that are peripheral. This hypothesis was tested (BONZI & LIDDY). Using abstracts from the PsycINFO database, words or phrases serving as anaphors were judged as being integral in 52% of the cases studied; the comparable value for abstracts from the INSPEC database was 68%. The authors concluded that the resolution of anaphora may indeed be important if the effectiveness of text searching is to be improved. This is an example of a conclusion that is based on the processing of abstracts but that may not apply to the full-text situation. Presumably, the redundancy of full text will create a situation wherein the frequency with which a topic occurs *explicitly* will generally reflect its importance in the text regardless of how many implicit references may be missed.

DOSZKOCS gives a useful general overview of natural-language processing in information retrieval. The relative merits of natural-language vs. controlled-vocabulary approaches to information retrieval are still debated. DUBOIS compares the two approaches, and SVENONIUS looks at the history of the issue and suggests areas for research that "would clarify it in such a way as to contribute to a rational basis for the design of retrieval tools such as thesauri" (p. 338). BAER & JOHNSON, considering in particular the OP AC situation, conclude that vocabulary control is even more important in the online environment than it is in manual systems.

As full-text databases become the norm, there looms a danger that the mere presence of the complete text may be viewed as a labor-saving substitute for subject indexing. YANCEY points out that the growth of information through full-text services will place even more importance on relevance and warns of the loss of retrieval capability through lack of subject indexing. A combination of full-text and subject-searching techniques to link past and present knowledge is presented as the preferable alternative.

TEUFEL describes an approach to text retrieval that he refers to as "*n*-gram indexing." The texts of abstracts are reduced to significant words through use of a stop list, then reduced further to word stems. The stems are converted into trigrams (e.g., the stem QUEUE would be reduced to QUE, UEU, and EUE); "high noise" trigrams are replaced by tetragrams or even pentagrams. Natural-language queries are processed in the same way. Retrieval consists of looking for the best matches between *n*-gram representations of documents and of requests. Teufel presents some results of tests using abstracts from the INSPEC database. Problems in the portability of natural-language queries from one database to another are addressed by DAMERAU.

AUTOMATIC INDEXING AND RELATED ACTIVITIES

For more than 30 years investigators have sought ways to replace human intellectual processing by computer processing of text. Methods investigated include automatic indexing by extraction or assignment, automatic extracting, the automatic organization of terms or documents into classes, automatic approaches to thesaurus construction or the development of networks of semantic relations among terms, and methods for matching natural-language requests against the text of documents or their indexed representations. SGALL & VRBOVA have described work in automatic indexing, automatic extracting, machine translation, and related aspects of text processing under way at Charles University in Prague.

VON KEITZ presents a brief overview of the three types of automatic indexing currently available: 1) inverted-file full-text indexing, 2) dictionary-based indexing, and 3) dictionary/rule-based indexing. The author asks what roles in automatic indexing should be played by humans and what roles should be played by machines. Although only full-text indexing is fully automatic and is the most frequently encountered, the dictionary and dictionary/rule systems provide higher precision; thus, better dictionaries and rules will yield better indexing. The author concludes that the human role should be one of continuing to develop better dictionaries and rules.

SUZUKI & TOCHINAI compare the keyword density method (originally used by Luhn) with a "mean order" method for extracting sentences in automatic abstracting, and DAS-GUPTA compares the Two-Poisson model of automatic indexing with inverse document frequency and discrimination value models. While the automatic extraction of "significant" words, phrases, or sentences from documents, based on frequency and/or positional criteria, has been successful for many years, automatic assignment indexing, involving even very small controlled vocabularies, has met with much less success. However, natural-language processing has progressed to the point at which assignment indexing by computer should now be possible. At least, machine-aided assignment indexing should be practicable. VLEDUTS-STOKOLOV, for example, describes experiments performed at BIOSIS in which terms from a limited vocabulary of 600 biological concept headings are assigned automatically to journal articles. The assignment is achieved by matching article titles against a semantic vocabulary containing about 15,000 biological terms, which, in turn, are mapped to the concept headings. The automatic aid to indexing developed at BIOSIS is described in detail, and the disambiguation techniques used are illustrated. While, overassignment and underassignment of terms still occur (i.e., the automatic procedures make some assignments that human indexers would not make and fail to make some that they would), automatic assignment indexing has certainly made some progress since the 1960s.

Machine-aided assignment indexing is also in place at the National Aeronautics and Space Administration (NASA). This work is described by BUCHAN but in insufficient detail.

As might be expected, considerable interest now exists in the possibility of devising "expert systems" to aid the indexing process. One example is the MedlndEx System (previously

referred to as the Indexing Aid System) being developed at NLM (HUMPHREY; HUMPHREY & KAPOOR; HUMPHREY & MILLER). Referred to as a "prototype interactive knowledge-based system," it uses an experimental frame language and is designed to interact with trained MEDLINE indexers by prompting them to enter MeSH terms as "slot fillers" in completing document-specific indexing frames derived from the knowledge-base frames.

MARTINEZ ET AL. describe another rule-based system. The American Petroleum Institute's (API) Central Abstracting and Indexing Service (CAIS) incorporates a rule-based, expert system founded on the API Thesaurus, which has been in operation since 1985. Terms automatically generated by the system (by matching abstracts against a knowledge base derived from the API thesaurus) and by API's human indexers are reviewed by a human editor, and the edited terms are added to print indexes and the online index. At present the base contains about 14,000 text rules.

SALTON (1988b) presents suggestions for the automatic indexing of monographs. The method proposed performs a syntactic analysis of the text, selects nominal constructs, weights the terms, and selects terms to act as index terms. Approaches to the machine-aided indexing of patents are discussed by SCHRAMM & BIELA.

ALADESULU studies methods of improving automatic indexing operations to make them more closely approach the intellectual level of human indexing. The approach used involves the recognition of phrases that are semantically equivalent but syntactically different. DYKSTRA (1987) observes that the clear rules of the PRECIS system lend themselves to the process of content analysis and automatic indexing. CONGREVE describes a project designed to evaluate the automatic production of PRECIS-based indexes.

Among other methods used for automatic indexing are user manipulation of index commands imbedded in the document (CHEN & HARRISON) and system manipulation of keywords in and out of context. LAMEIN examines the advantages and disadvantages of keyword-out-of-title indexing and describes its use in the law library of the Free University of Amsterdam.

The processing of the text of a request against the text of a document collection can be considered as essentially a pattern-matching operation. The objective is to retrieve items in a ranked order, with those that best match the request at the top of the ranking. One way of achieving such a ranking is by weighting the search terms by the frequency with which they are associated with items already known to be relevant, their rate of occurrence in the database as a whole, or other statistical properties. ROBERTSON describes one weighting formula that he considers an improvement over those previously used. SALTON & BUCKLEY summarize findings of research on automatic term weighting and present models for comparison with more complex techniques of content analysis. CHOROS & DANILOWICZ describe an approach to "relative indexing," in which the weights assigned to descriptors associated with documents are modified on the basis of user relevance feedback.

BUELL discusses problems associated with the fuzzy-set approach to weighted retrieval. The calculation of term discrimination values is discussed by WILLETT, EL-HAMDOUCHI & WILLETT, and CROUCH, while BARTSCHI presents a general mathematical framework for looking at retrieval approaches involving term weighting and the ranking of output, and MURTAGH describes hierarchic clustering methods applicable to information retrieval. CAN & OZKARAHAN (1987) also deal with term discrimination values. They introduce a "cover coefficient" and describe how this can be used in computing the discrimination value for a term.

FAGAN (1987; 1988) compares two methods for automatically extracting phrases from

texts to serve as content indicators. Nonsyntactic methods are based on simple text characteristics, such as word frequency and word proximity, while syntactic methods selectively extract phrases from parse trees generated by an automatic syntactic analyzer. Retrieval tests were inconsistent but tended to indicate that the nonsyntactic methods produced better results. Nevertheless, Fagan suggests that the syntactic approach does have certain advantages and has a greater potential for improvement than does the nonsyntactic method.

The ranking of documents in "automatic" information systems is usually based on probabilistic, vector, or fuzzy-logic criteria. LOSEE (1988), building on the work of BOOKSTEIN, presents a probabilistic sequential learning model for ranking. The proposed system will retrieve documents, accept feedback on the retrieved items, and "learn" from the feedback to enhance future performance, the relevance feedback being an intrinsic element in the sequential learning model itself. An earlier article (LOSEE, 1987) describes how coordination-level matching can be used for ranking outputs from retrieval systems incorporating sequential learning. CROFT (1986) describes a method for integrating Boolean approaches with probabilistic retrieval methods. He claims that term dependencies derived from queries, when incorporated into a probabilistic retrieval model, can improve performance. The term dependencies can be derived automatically from Boolean queries or from user selection of important phrases from their natural-language queries.

RADECKI (1988a; 1988b), MARON, LOSEE & BOOKSTEIN, FOX & KOLL, S ALTON (1988a), and COOPER all deal with the limitations of conventional Boolean searching methods and propose ways in which such approaches can be improved (e.g., by incorporating ranking methods).

Relevance feedback is usually considered an essential element in any probabilistic retrieval method, and this implies the ability of the searcher to locate "a few relevant items" in a database. One way of achieving this is to match the query against clusters of items rather than against individual items. PANYR considers the place of cluster analysis in information retrieval along with possible search strategies to exploit clusters. GRIFFITHS ET AL. have compared various clustering methods and found that the best retrieval results were achieved by procedures that divide a database into many small clusters. This led them to propose that the optimal cluster will consist of only two items, the ones that are most similar (nearest neighbors). However, further tests showed that searches based on nearest-neighbor clusters did not perform any better than conventional "best-match" searches, although they retrieved a different set of items. Consequently, these authors propose that a retrieval system incorporate both approaches. SALTON ET AL. discuss the use of automatic relevance feedback techniques with Boolean query statements. An extended or "fuzzy" Boolean logic approach, which relaxes the normally strict interpretation of the Boolean operators, can improve search performance.

ENSER examines clustering techniques using terms from tables of contents, title, and back-of-the-book indexes, and concludes that this technique is viable in a book/text database.

SHAW (1986) looks at the empirical significance of document clusters (he refers to them as "partitions") as a function of term weight and similarity thresholds. In related work SHAW (1985) also looks at the validity of partitions formed on the basis of co-citation.

Approaches to the automatic indexing/classification of documents are generally based on data derived from a document/term matrix, showing which index terms or text words are associated with which documents. Documents may be grouped according to such factors as the frequency with which a term occurs in a document and the frequency with which it occurs in the database as a whole. The relationships between documents and terms need not be considered

"absolute." For example, words that do not occur in a document may nevertheless be judged "close" to that document when they tend to co-occur in other contexts with the words that do occur frequently in the document. DEERWESTER ET AL. propose an approach to indexing based on the "latent" relations among terms and documents, derivable from the document/term matrix. They refer to this as "latent semantic indexing." The model uses a reduced set of about 100 "descriptive parameters" derived by the linear decomposition of a document/term matrix. Each term, document, and query can be represented by values on this small set of orthogonal dimensions, which may be considered as "artificial concepts." The investigators claim that results achieved in retrieval tests for the method ranged from considerably better to roughly comparable with performance based on weighted keyword searching.

A more abstract, mathematical discussion of the analysis of weighted graphs in the clustering of items (e.g., documents or terms) is given by GOETSCHEL, while CAN & OZKARAHAN (1985) compare two clustering algorithms in terms of stability and similarity factors.

YAKUBOVITZ refers to an associative retrieval system that can overcome some problems of text retrieval without the need for daily updating of a system thesaurus. This system links keyword-bearing documents with adjacent, associated documents having only one keyword in common to form an associative path. An algorithm for the construction of a path that changes keyword three times is presented as an example.

THÖNSSEN reports on an interface that connects automatic indexing programs with automatic thesaurus maintenance programs. The interface can be used with a personal computer.

STREETER & LOCHBAUM present details on an expert/expert locator (EEL), which matches requests for information with technical organizations. The technical organizations in EEL are represented by their documents, and these documents provide the system with input. The automatic indexing places terms and organizations in a 100-dimension semantic space and determines similarities among organizations on the basis of their use of terms. When queried, the system computes the degree of similarity between the request and all objects in this structure, retrieving those that are most similar. The approach is similar to the latent semantic indexing described by DEERWESTER ET AL.

Another approach to "automatic" retrieval consists of the development of natural-language interfaces that allow a user to enter queries as phrases or sentences without the need to deal with controlled vocabularies or to express logical relationships among terms. Various natural-language interfaces have been developed over the years. BISWAS ET AL. introduce an approach that uses fuzzy-set techniques, and they describe it in considerable detail (see BUELL for a discussion of some problems associated with the fuzzy-set approach to information retrieval). CLEMENCIN describes a natural-language interface to the "yellow pages" of France's online telephone directory, while SPIEGLER & ELATA propose a model for analyzing a query at a local workstation to determine whether it is "answerable" before submitting it to some accessible database.

Rather than mapping natural-language expressions to a limited number of controlled terms, words occurring in text can be decomposed into smaller semantic units (e.g., "thermometer" could be represented by "device," "measurement," and "heat"). This is the basis of "semantic analysis" and the "semantic code" that was applied to information retrieval at Western Reserve University more than 25 years ago. SMETÁČEK describes the SEMAN system that will decompose text words into 630 distinctive "semantic features" (e.g., "being of the female sex," "being a metal"). He mentions several possible information retrieval applications but does not elaborate on them.

BELONOGOV ET AL. compare the performance of a retrieval system based on automatic indexing with the performance of a system based on text searching. They conclude that the system with automatic indexing has significantly better recall/precision characteristics and is faster than the other approach. Also, because low-performance terms can be eliminated, the database can be smaller. BLAIR & MARON, using IBM's STAIRS (Storage and Information Retrieval System) for full-text legal retrieval, reported average precision values of around 75%; but recall values of only about 20%. SALTON (1986) comments on these results and suggests that they are typical of conventional retrieval operations. He presents results for studies that have compared conventional with automated approaches and emphasizes that the future lies with the latter.

BLAIR (1988) reviews the basic model of a relational document retrieval system and demonstrates how documents can be linked during a search in a relational system. He presents an extended model that includes weighted subjects, associative features such as thesaurus links, citation indexing, and co-occurring terms.

At a more general level, CANISIUS discusses potential uses of knowledge-based systems in information service applications and argues that the information profession could become redundant if it fails to exploit the capabilities of such systems, while WORMELL and BALDACCI deal with artificial intelligence and expert systems applied to information retrieval problems. SPARCK JONES (1988), on the other hand, questions the need for artificial intelligence applications in information retrieval systems.

CITATION RELATIONSHIPS

Related documents can be grouped on the basis of direct citation, co-citation, or bibliographic coupling as well as through the more conventional methods of subject indexing. A number of recent studies deal with various aspects of these citation relationships in information retrieval.

PAO (1986; 1988) and PAO & FU have compared results of searches based on citation relationships with results from conventional subject searches in MEDLINE. Not surprisingly, they find that the two methods are essentially complementary, each retrieving some relevant items not found by the other. One conclusion was that the conventional approach by descriptors could retrieve only about half of the "quality" papers. In reviewing their own bibliographic references, however, it is distressing to note that none of the items cited was published before 1979, giving the impression that studies of this kind are relatively new. In fact, comparisons of citation retrieval (direct citation and bibliographic coupling) with conventional descriptor retrieval go back more than 20 years. Moreover, the complementarity of citation and traditional approaches was demonstrated long ago and is now taken pretty much for granted. We really don't need more studies to prove it.

MCCAIN reports a similar study. Results from co-citation searches in SciSearch were compared with results from conventional searches in BIOSIS Previews. The subject was the genetics of fruit flies. One of McCain's conclusions is that co-cited author searching "is capable of capturing a large percentage of relevant documents in a broad subject retrieval." TRIVISON (1986; 1987) compares items retrieved by subject indexes and citation indexes in the field of information science.

Unfortunately, neither conventional subject indexing nor citation links offer a foolproof way of linking documents or groups of documents that are "logically" related. SWANSON (1987) points to two groups of logically related articles — one on the effects of dietary fish oils on changes in the blood and the other on the possible beneficial effects of similar blood changes for

patients with Raynaud's disease — that are not closely related by co-citation, bibliographic coupling, or statistical associations among assigned descriptors. (In a personal communication Swanson has indicated that while the two literatures do use similar text terms, the sheer size of the literature based on common terms makes linkage through literature searching almost impossible.) In a similar study SWANSON (1988) looks at the problems of linking the literature of magnesium to the literature of migraine.

SHAW (1985) raises doubts about the validity of some subject relationships supposedly demonstrated by co-citation. Classes formed by co-citation can be statistically invalid even at a high co-citation level. However, critical thresholds that define the limits of statistical validity can be identified. Within these limits there does exist "a narrow region of statistical validity where the associated structures are not an artifact of the clustering procedure and can be interpreted" (p. 38).

KWOK (1985) refers to the fact that reference/citation links can be used in information retrieval to form an "augmented collection" of retrieved items. That is, when a search strategy is applied to a database in the normal way, using text words or controlled terms, the set of items thus retrieved can be augmented by those items linked to them through bibliographic citations. He suggests that the set of terms associated with the items originally retrieved might be augmented by the addition of terms drawn from the items that they cite. These new terms could be index terms assigned to the cited items, or they could be text expressions drawn from abstracts or titles. He suggests that augmentation by drawing terms from the titles of cited items is most practicable. This is virtually what Mary Elizabeth Stevens was working on more than 20 years ago (STEVENS). SALTON & ZHANG have tested the value of augmenting the set of terms associated with retrieved items by adding title words drawn from "bibliographically related" items. Title words were drawn from: 1) items cited by the retrieved items, 2) items citing the retrieved items, and 3) co-cited items. The authors conclude that while many "useful" content words can be extracted in this way, many terms of doubtful value will also be extracted; further, the procedure is not sufficiently reliable to warrant inclusion in operating retrieval systems. KWOK (1988), on the other hand, reinterprets their results and concludes that the enhancement may still be worth further investigation.

REES-POTTER looks at the potential for using citation, co-citation analysis, and citation context analysis in the updating of thesauri or other controlled vocabularies. She concludes that the analysis of citation content may be used in the development of indexing vocabularies in specialty areas.

CONCLUSION

This review strongly suggests that subject analysis continues to be an area of great interest and activity. The increasing impact of electronic technology, combined with the ongoing expansion of that technology's capabilities, seem certain to have a profound effect on the progress of subject analysis, an effect that will no doubt be expressed in future *ARIST* chapters on this topic. The authors hope that continued technological advances will not only stimulate ever-increasing inquiry and experimentation, but that sharing these advances, inquiries, and experiments with less technologically developed countries will also bring about more efficient and more sophisticated means of subject analysis and access on a global scale.

Readers of this review who have been actively involved in information science for a considerable time will recognize that substantial progress has occurred in the past 25 years in certain areas; automatic indexing, full-text searching, and end-user searching are obvious examples. This progress has been accompanied by the increasing convergence of information

science and library science. The advent of the online public access catalog (OPAC) has promoted greatly increased interest in the library community in improving subject access. Indeed some of the most interesting work in this area is now being performed in the traditional library setting, which was not generally true 20 or more years ago. It is interesting to note how history repeats itself. In the 1950s and 1960s much of the progress in information retrieval occurred through the efforts of scientists, engineers, lawyers, and others who were not information professionals. These individuals were not familiar with the literature of library science, and some reinvention of the wheel occurred. Today a reverse situation may be occurring, with members of the library community reinventing methods that were developed (and perhaps tested and rejected) outside the community many years ago. The field of information science seems to have a short collective memory. We know of work done three or four years ago but are unaware of, or have forgotten, work done much earlier. While much (perhaps most) of the early work is outdated, some of it is still highly relevant. *ARIST* is of immense value in providing a review and synthesis of research in broad areas performed during relatively short periods of time, but it does not obviate the need for longitudinal reviews, covering perhaps 20 or 30 years, on more specific topics.

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